§20. High Performance A15 Compound Superconductors Prepared Through a New Route

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Generation of high magnetic field is indispensable for the advancement of fusion facilities. Present author recently fabricated new Nb_3Sn conductors using a composite of Ta-Sn core and Nb (Nb-Ta) sheath[1, 2]. The non-Cu J_c of the conductor exceeds $1x10^4 A/cm^2$ at 23T and 4.2K after the reaction at 900°C. In this fiscal year, effects of Cu addition to the Ta-Sn core on the structure and high-field performance of the new Nb_3Sn conductor have been studied optimizing the Ta-Sn-Cu ternary core composition. The Cu addition to the core facilitates the reduction of reaction temperature.

The mixed powder of Ta and Sn was reacted at 950°C for 10h in an alumina crucible in vacuum, the atomic ratio of Ta /Sn in the mixed powder being 6/4, 6/5 and 4/6. 1~10wt% Cu was added to the Ta+Sn mixed powder. The resulting Ta-Sn or Ta-Sn-Cu powder was encased in a Nb-4at%Ta tube, 8/5mm in outer/inner diameter, and then fabricated into a tape of 4mm-wide and 0.6mm-thick. The specimens were heat-treated at temperatures between 750°C and 950°C for 80h in vacuum for the diffusion reaction to form a Nb_3Sn layer between the sheath and the core.

Thick and uniform Nb_3Sn layers containing several at% Ta are synthesized by the diffusion reaction. The thickness of the Nb_3Sn layer is a few times larger than that formed in the bronze-processed Nb_3Sn conductors with similar specimen configuration. The reaction temperature producing enough thick Nb_3Sn layer is reduced from 900°C for the specimen without Cu addition to 750°C for that with 7.5wt% Cu addition to the core. The Nb_3Sn grain size is significantly decreased by the reduction of reaction temperature.

The specimen with 1wt% Cu addition to the core reacted at 825°C shows nearly the same critical current (I_c) versus magnetic field performance as that of the specimen without Cu addition and reacted at 900°C. The increase in I_c with decreasing field becomes predominant by the Cu addition to the core, which may be caused by the grain refinement of Nb_3Sn. The specimen with 2wt% Cu addition reacted at 800°C shows a non-Cu critical current density (J_c) of $1.3x10^4 A/cm^2$ at 22T and 4.2K.

Fig. 1 shows I_c at 21T and 23T versus reaction temperature of specimens with 7.5wt% and 10wt% Cu addition to the core. Specimens with Ta/Sn composition ratio of 6/5 and 6/4 in the core seem to show maximum I_c after the reaction at a temperature bellow 750°C. Non-Cu J_c of about $1x10^4 A/cm^2$ is obtained at 21T and 4.2K after the reaction at 750°C in the specimen with 7.5wt% Cu addition to the core. Higher Sn concentration in the core seems to yield larger I_c referring the results for specimens with 4/6 and 6/4 core composition. However, higher Sn concentration in the core shifts the optimum reaction temperature to higher side, which may be due to the lower Sn/Cu composition ratio in the core.

In conclusion, larger amount of Cu addition to the Ta-Sn core causes larger reduction of optimum reaction temperature. Moreover, Cu addition to the core is favorable to produce finer Ta-Sn powder. This effect is practically important for the fabrication of conductors with thinner filament diameter. Meanwhile, the field keeping a non-Cu J_c of $1x10^4 A/cm^2$ at 4.2K in the conductor is shifted from 23T to 22T by 2wt% Cu addition, and to 21T by 7.5wt% Cu addition. Cu addition yields more significant increase in J_c with decreasing magnetic field. Thus, a variety of J_c versus magnetic field performance can be obtained by adjusting the amount of Cu addition to the core and the reaction temperature in the present new Nb_3Sn conductors.

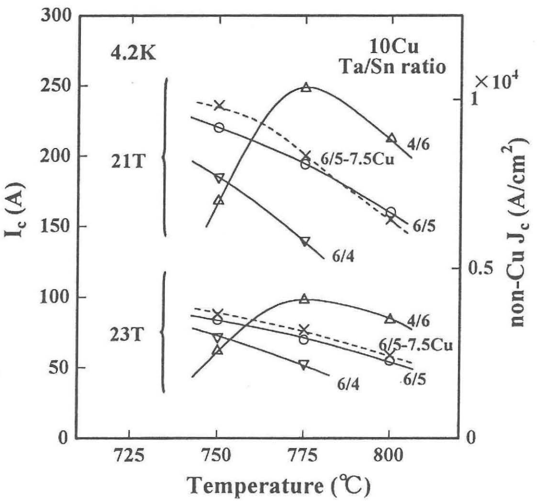

Fig. 1. I_c and non-Cu J_c at 21T and 23T versus reaction temperature of the specimens with 7.5wt% Cu and 10wt% Cu addition and different Ta/Sn composition ratio in the core.

Reference

1) Tachikawa, K. et al.: Adv. Cryogenic Engineering (Materials), **46,** (2000) 1027-1034.
2) Tachikawa, K. et al.: IEEE Trans. Appl. Supercond., **11,** No.1 (2001) 3663-3666.